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Investigation of Hydrogeological and Hydrogeochemical Properties of Muradiye-Çaldiran (Van) Geothermal Field, Eastern Turkey

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Abstract

The study area that is situated in northeastern of the Lake Van contains hot and cold water in the Muradiye-Çaldıran basin. There are Paleozoic-Mesozoic metamorphic units based on the stratigraphic sequence in the region and that units include reservoir rocks in the geothermal field. There are Quaternary alluviums, Plıyo - Quaternary volcanic rocks such as basalt, basaltıc tuf, tuf-basalt, basalt with gravel and Late Paleozoic metamorphic series in the field from top to base, respectively. Quaternary alluviums and Plıyo - Quaternary volcanic rocks show the cap rock features. Structurally, there are right-lateral faults with NW-SE directional, which constitute in Neo-tectonic period, Middle Miocene in the field. Aim of this study is investigation of hydrogeological and hydrogeochemical properties of a geothermal field, eastern Turkey. In this study, samples were taken from 34 points including springs, wells, and analyzed in Muradiye-Çaldıran geothermal field; eight of them are hot water, one of them is mineralized water and 25 of them are cold water. Geothermal springs are parallel to the faults. Also, physical measurements such as pH, EC and temperature were applied in-situ and as a result of measurements temperature changes between 8.8 °C and 34.7 °C, pH changes between 6.80 and 8.81 and EC changes between 60 and 3420 µS/cm. When geophysical studies examined which are carried out in the center of the field (Çaldıran-Ayrancılar) for the purpose of investigation of geothermal energy resources, is seen a little geothermal activity zone, is not seen very active tectonic and detected a geothermal field with low enthalpy. In geophysical studies which are carried out for the purpose of detecting spread of aquifer and layers in the general of the field, thickness of alluviums are nearly 25 meters and volcanic rocks nearly 120 meters and thickness of metamorphic series is not known.

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Hydrogeochemical investigations were evaluated by using semi-logarithmic Scholler, Piper and Durov diagrams. As

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a result of the evaluation, water in study area include HCO3+CO3 at the high levels, Cl level is low at the most of the samples and only a few samples have high chlorine. According to the ion content, hot and mineralized water are Ca - HCO3 type water and cold water are Mg-HCO3 and Ca-Mg- HCO3 type water.

1. Introduction

The Muradiye-Çaldıran geothermal field, which includes the thermal water of Ayrancılar (Çaldıran), Buğulukaynak (Çaldıran) and other little springs in Muradiye and Çaldıran is located in the NW- SE and NE-SW trending the Muradiye-Çaldıran basin in the eastern part of Turkey (Fig. 1).

Thermal water in the region has been used for bathing by people but they have never operated a spa. Although the thermal springs have been known since historical times, there is no detailed study of the geothermal field. Chemical analyses of these thermal waters are only rarely discussed in some articles (Oruç et al., 1976; Aydın et al., 2013).

Fig. 1. Location map of the study area.

The Muradiye-Çaldıran geothermal field and surrounding areas also include an important volcanic mountain called Tendürek Volcano. The Tendürek Volcano is located in the northeastern of the Muradiye-Çaldıran geothermal field. Therefore, there are many volcanic rocks such as basalt, basaltıc tuf, tuf-basalt and basalt with gravel in the region. The aim of this study is the investigation of hydrogeological and hydrogeochemical properties of the Muradiye-Çaldıran geothermal field. Thermal water samples from the study area were collected from 8 springs (samples 15CA, 21CA, 29CB, 27CK, 28CB, 2MO, 8MU, 10MY) and 1 mineralized water spring (sample 32CE) (Fig. 3). Cold water samples from the study area were collected from 25 points; 11 of them from well (samples 1MO, 3MK, 7MU, 11M, 17CY, 22CY, 24CK, 26CK, 33CD, 35 CH, 36CA) and 14 of them from springs (samples 5MKS, 6MTPZ, 9MB, 12M, 13CA, 16CK, 18CY, 19CA, 20CY, 23CK, 25 CK, 30CS, 31 CE, 34CH). Temperature, electrical conductivity and pH values were measured at spring and wellhead conditions.

The remaining chemical constituents and some trace elements were analyzed in the Canada ACME Laboratories by using ICP-MS method and CO_3 (carbonate), HCO_3 (bicarbonate), SO_4 (sulfate) and F (fluorid) were analyzed by using chemical cuvette tests. In addition, geothermal studies were made by two foundations in the Muradiye-Çaldıran field.

2. Geological and hydrogeological settings

The basement of the study area is metamorphic rocks, which belong to the Bitlis Massif, Paleozoic flysch, Gevaş ophiolites, the Tozutepe Formation, and Çardak volcanic rocks. In addition, there is the Van Formation consisting of flysch, Adilcevaz limestones and the Ahlat Formation consisting of conglomerates above the Çardak volcanic rocks. The Plio - Quaternary basalt, basaltic tuff, tuff-basalt, basalt with gravel and Quaternary alluviums are located in the Muradiye-Çaldıran basin, covering these sedimentary and metamorphic rocks (Fig. 2).

Most of the thermal water is discharged along the NW–SE trending faults that form the Muradiye-Çaldıran basin. The circulation of thermal water is closely related to a major fault and fracture zones. Fractured metamorphic rocks of the Bitlis Massif such as various schist and especially marbles are assumed the main reservoir rocks for the Muradiye-Çaldıran thermal water.

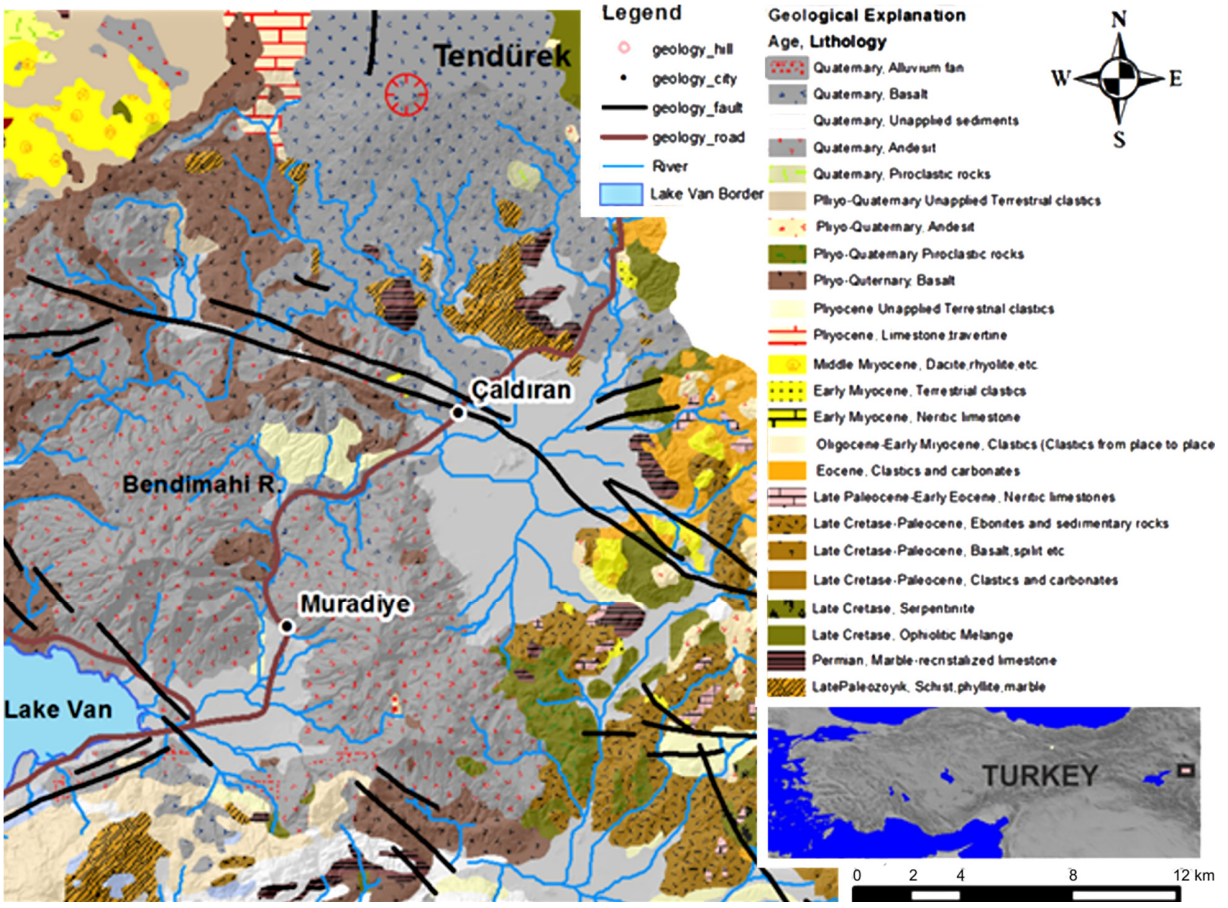

Fig. 2. Geological map of the study area.

There are three rock types including permeable, semi-permeable and impermeable in the Muradiye-Çaldıran field as hydrogeological. Impermeable units, which are volcanic rocks such as basalt, basaltic tuff, tuff-basalt, basalt with gravel and ophiolitic rocks, make up the general field. Second one; permeable rocks that are alluviums, limestone, carbonates and marbles are distributed on the field.

Third one, semi-permeable debris rocks have been distributed on the field. In addition, groundwater levels have been determined and groundwater flow direction directs to the SW (Fig. 3).

3. Results and discussion

3.1. Geophysical studies

Two geophysical studies were carried out in the study area by Arslan et al. (2003) from MTA (Mine Exploring Foundation) and Okan (1981) from DSI (State Hydraulic Works). The purpose of these studies was investigating geothermal energy resources and detecting distribution of aquifer and layers. Geothermal resources were investigated in the Çaldıran-Ayrancılar geothermal field, which is center of the study area, by MTA as shown in Figure 3.

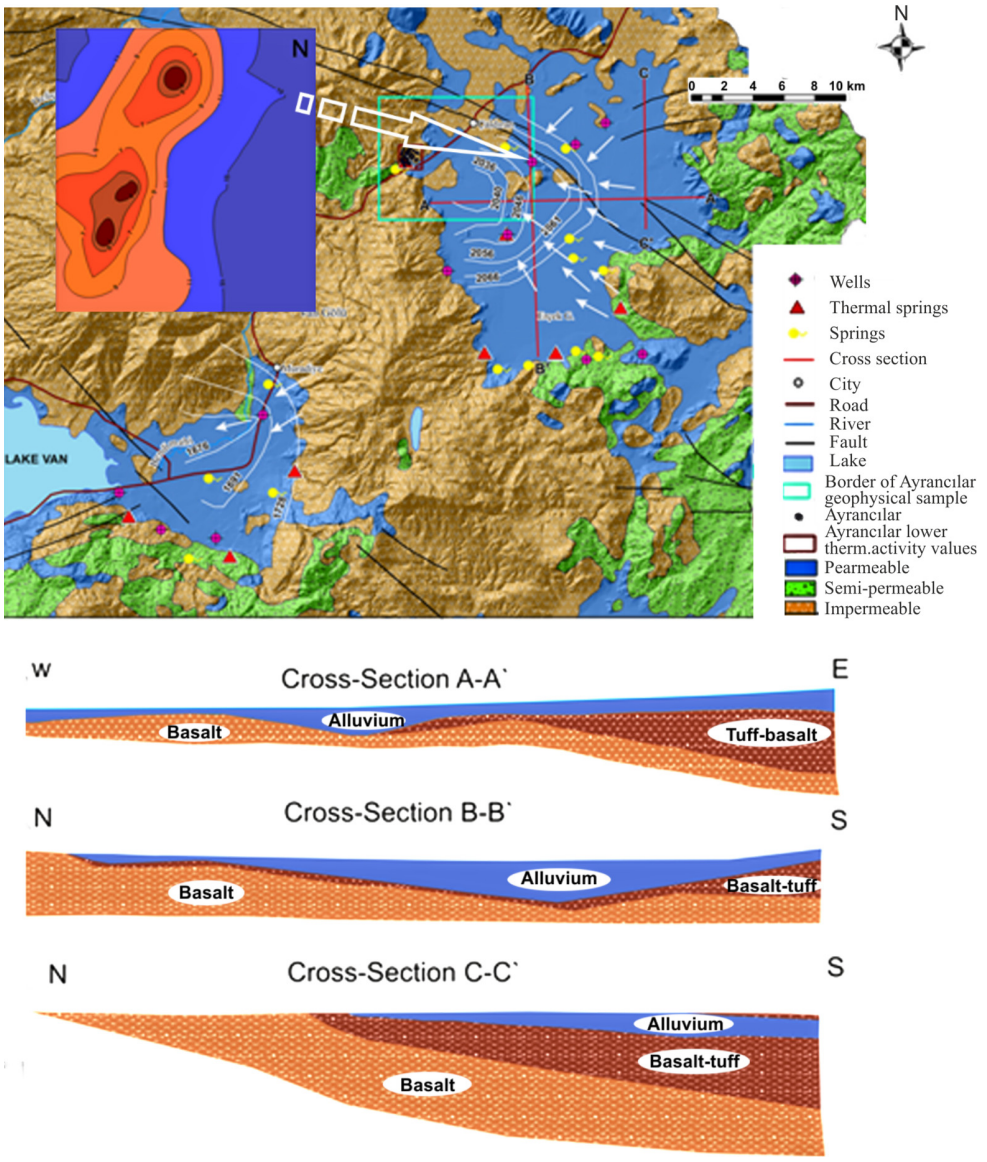

Fig.3 Hydrogeological map of the study area (Modified from Düzen, 2011).

Gravity and electric-resistivity methods were applied to the area and vertical electrical drilling applied at the 34 points by using a Schlumberger electrodes arrangement. A resistivity map was prepared by using lowest resistivity values at each point purpose of geothermal energy activity (Fig. 3). So a small geothermal activity zone with low

enthalpy was detected.

The aquifer thickness was measured in Muradiye-Çaldıran field by Okan (1981) from DSI. These geophysical studies were carried out for detecting distribution of aquifer, layers in the general of the field, thickness of alluviums are nearly 25 meters, and volcanic rocks nearly 120 meters and thickness of metamorphic series is not known.

3.2. Water chemistry

Table 1 lists the chemical composition of water samples and water types. A series of diagrams showing the relative concentrations of the thermal fluids and cold water were used to investigate the relations between the ions. Some GIS (Geographic Information Systems) based computer programs were used to evaluate mineral speciation and to construct the diagrams. Piper, Scholler and Durov diagrams were showed in Figure 4, Figure 5 and Figure 6 for all sample points including cold water and thermal and mineralized water.

Table 1. Chemical analyses of thermal water and cold ground water (EC: electrical conductivity).

NO	pH	EC (µs/cm)	T (oC)	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HC03 mg/l	S04 mg/l	CI mg/l	CO3 mg/l	F mg/l	B µg/L	Water Type
1MO	7.89	1465	22.1	170.63	95.35	65.65	4.41	498.9	129	149	0	1.58	553	Ca-HCO3
2MO	7.75	302	23.9	63.02	8.79	8.12	1.14	243.4	62.1	1	0	0.93	50	Ca-HCO3
3MK	7.69	636	21.6	69.96	42.51	45.43	10.69	547.6	66	11	0	1.44	839	Mg-HCO3
5MKŞ	7.61	608	26.8	79.99	35.61	17.24	7.71	425.9	65.2	2	0	1.42	171	Ca-HCO3
6MTPZ	8.00	344	23.3	54.22	13.31	10.43	2.03	456.3	64.5	2	0	1.24	62	Ca-HCO3
7MU	8.05	556	14.5	90.89	28.39	17.61	2.98	243.4	66.3	9	0	1.18	130	Ca-HCO3
8MU	7.82	568	20.2	93.40	25.11	25.75	1.93	425.9	64.6	13	0	1.39	175	Ca-HCO3
9MB	8.08	267	23.7	35.48	9.94	14.87	1.53	182.5	64.8	<1	0	1.01	245	Ca-HCO3
10MY	8.05	143	26.7	15.25	5.27	4.24	0.85	121.7	61.8	<1	0	0.89	13	Ca-HCO3
11M	7.96	543	16.5	68.53	22.14	49.09	6.90	407.6	62.4	6	0	1.7	549	Ca-HCO3
12M	8.10	366	20.5	45.10	13.33	19.89	26.57	231.2	66.6	12	0	1.37	135	Ca-HCO3
13ÇA	8.12	180	30.2	25.22	4.03	13.23	2.85	194.7	64.4	<1	0	1.8	39	Ca-HCO3
15ÇA	7.74	3420	34.7	117.30	26.00	724.00	195.00	11863.8	179	*	0	4.35	59363	Na-HCO3
16ÇK	8.02	431	16.4	67.18	19.88	21.48	6.59	400.9	65.1	2	0	1.45	347	Ca-HCO3
17ÇY	8.41	320	16.4	43.78	9.38	16.78	4.79	291.4	66.2	3	0	1.23	104	Ca-HCO3
18ÇY	7.6	550	8.8	11.51	10.67	123.25	12.91	785.4	63	5	0	4.34	427	Na-HCO3
19ÇA	7.5	510	17	11.47	10.80	121.71	12.67	770.8	63	5	0	3.94	413	Na-HCO3
20ÇY	8.39	725	20.3	99.54	45.70	21.08	1.54	93.7	64	45	0	1.2	156	Ca-HCO3
21ÇA	8.81	136	20.2	18.26	2.09	11.98	0.66	40.2	66	<1	0	0.94	43	Ca-HCO3
22ÇY	8.67	711	18	72.61	67.88	13.32	1.29	78.5	62	51	0	0.97	93	Mg-HCO3
23ÇK	8.61	347	17	53.94	14.73	15.66	5.64	343.1	64	5	0	0.94	76	Ca-HCO3
24ÇK	8.07	103.6	21.3	11.94	0.41	15.95	0.39	23.7	60.3	<1	0	0.22	33	Na-HCO3
25ÇK	8.79	88.9	23	10.20	1.14	9.19	0.53	32.2	61	<1	0	0.92	34	Ca-HCO3
26ÇK	7.59	1938	18.1	164.29	134.60	144.33	73.15	4450.4	121	161	0	0.96	2104	Mg-HCO3
27ÇK	7.43	1696	20.7	168.00	104.83	167.89	48.42	2945.9	66.4	48	0	0.85	8717	Mg-HCO3
28ÇB	7.29	1155	33.5	93.59	79.25	98.86	26.72	1625.6	63.8	16	0	1.19	2082	Mg-HCO3
29ÇB	8.42	60	20.7	7.46	1.87	3.24	1.47	89.4	59.9	<1	0	0.89	54	Ca-SO4
30ÇS	8.76	145.9	13.7	18.58	7.15	7.38	1.00	60.8	65	<1	0	0.48	65	Ca-HCO3
31ÇE	7.30	202	15.4	28.62	8.79	12.26	4.47	272.0	62.2	<1	0	0.92	76	Ca-HCO3
32ÇE	6.8	496	19.1	45.41	40.84	31.20	9.83	598.1	58.4	<1	0	1.36	113	Mg-HCO3
33ÇD	8.12	610	18.4	91.49	17.87	16.12	33.43	2033.9	70.2	57	0	1.34	72	Ca-HCO3
34ÇH	7.98	503	24.5	11.74	11.05	124.92	12.74	775.1	59	5	0	4.16	453	Na-HCO3
35ÇH	8.38	1979	13.7	86.61	148.27	266.73	19.60	1192.5	199	166	0	3.23	1148	Mg-HCO3
36ÇA	8.51	1395	14.5	81.40	101.98	143.68	71.06	4323.3	128	113	0	2.82	814	Mg-HCO3

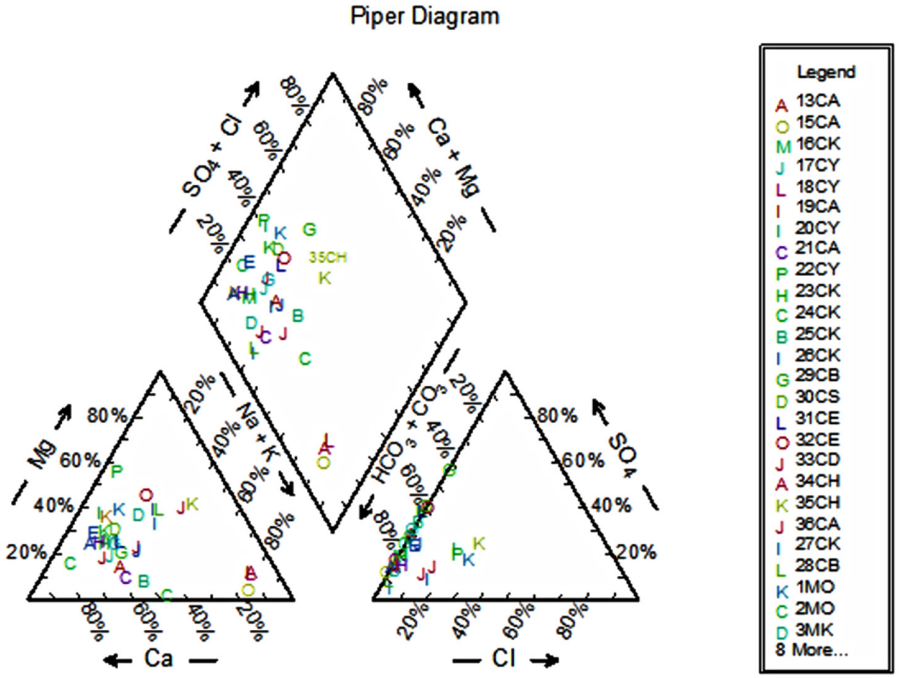

Fig. 4. Piper diagram of all sample points in Muradiye-Çaldıran field.

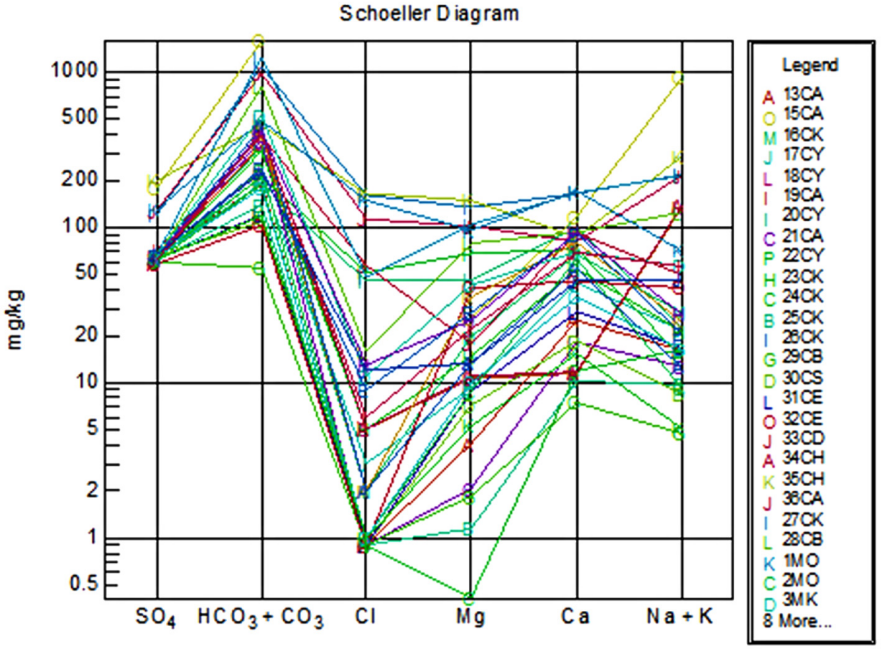

Fig. 5. Schoeller diagram of all sample points in Muradiye-Çaldıran field.

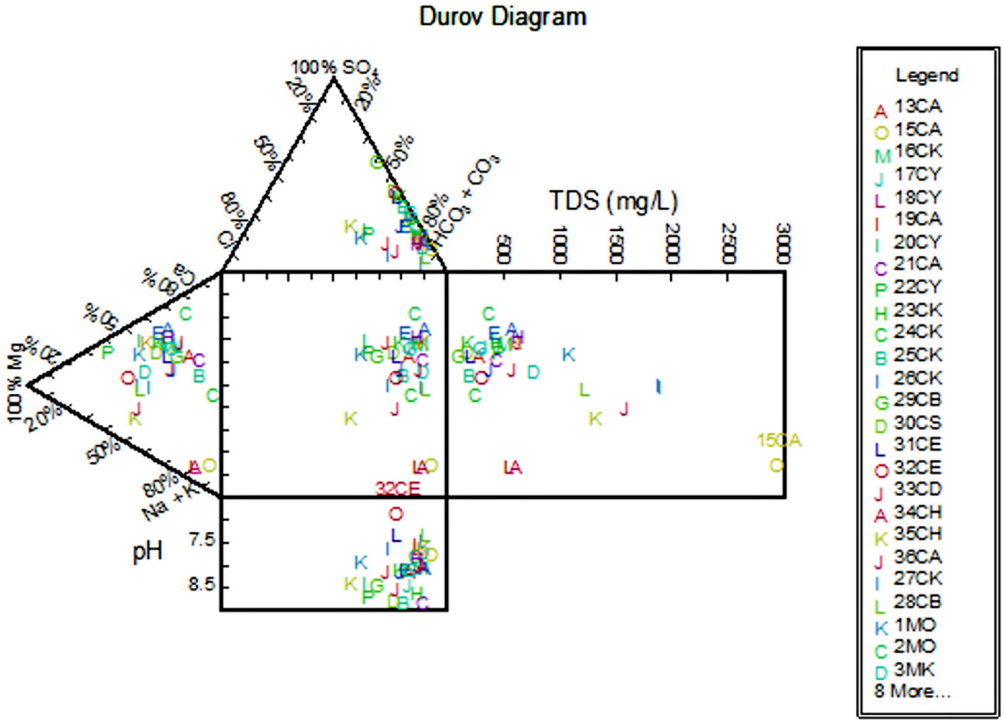

Fig. 6. Durov diagram of all sample points in Muradiye-Çaldıran field.

4. Conclusion

Most of the thermal water is discharged along the NW–SE trending faults that form the Muradiye-Çaldıran basin. The circulation of thermal water is closely related to major fault and fracture zones. There are 3 rock types including permeable, semi-permeable and impermeable rocks in the hydrogeological Muradiye-Çaldıran field. Permeable rocks are alluviums, limestones, carbonates and marbles.

According to geophysical studies, the thickness of alluviums is nearly 25 meters and volcanic rocks nearly 120 meters strong. The thickness of the metamorphic series is not known. A small geothermal activity zone with low enthalpy was detected in the Çaldıran-Ayrancılar geothermal field.

Thermal and cold water from the study area can be divided into 3 distinct types. Most of water samples (20 point) are of the $CaHCO_3$ type. $MgHCO_3$ (8 point) and $NaHCO_3$ (5 point) type waters form the second and third groups. Only one of the samples is Ca-SO_4.

The groundwaters are freshwater and dominant water types are Ca–HCO_3 and Mg-HCO_3. Chemical elements indicate an origin controlled by the dissolution of carbonate rocks. Because of the evaluation, water in study area included HCO_3+CO_3 at high levels; the Cl level was low in most of the samples.

Water quality assessment shows that in general, the water is suitable for drinking and other domestic and irrigation purposes. Ionic concentration, pH and EC parameters in the Muradiye-Çaldıran province suggest that climate and lithological units are a major controlling factor of groundwater chemistry.

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References

1. Arslan, S., Şahin, H., Hacısalihoğlu, 2003. MTA (Maden Tetkik ve Arama Genel Müdürlüğü), Jeofizik Etütleri Dairesi, Van, Türkiye.
2. Aydın, H., Mutlu, H., Kazancı, A., 2013. Çaldıran (Van) jeotermal sahasının hidrojeokimyasal özellikleri. 11. Ulusal Tesisat Mühendisliği Kongresi, İzmir, 71
3. Düzen, H., 2011. Van Gölü Su Seviye Değişimlerine Hidrojeolojik Yaklaşım. Yüksek Lisans Tezi, Yüzüncü Yıl Üniversitesi, Fen Bilimleri Enstitüsü, Van.
4. Okan, S.,1981. Muradiye-Çaldıran ovaları planlama kademesinde jeofizik etüt raporu. DSİ (Devlet Su İşleri Genel Müdürlüğü), Jeoteknik Hizmetler ve Yeraltısuları Dairesi Başkanlığı, Van, Türkiye.